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# Caring for Critically Ill Children With Suspected or Proven Coronavirus Disease 2019 Infection: Recommendations by the Scientific Sections' Collaborative of the European Society of Pediatric and Neonatal Intensive Care

**OBJECTIVES:** In children, coronavirus disease 2019 is usually mild but can develop severe hypoxemic failure or a severe multisystem inflammatory syndrome, the latter considered to be a postinfectious syndrome, with cardiac involvement alone or together with a toxic shock like-presentation. Given the novelty of severe acute respiratory syndrome coronavirus 2, the causative agent of the recent coronavirus disease 2019 pandemic, little is known about the pathophysiology and phenotypic expressions of this new infectious disease nor the optimal treatment approach.

**STUDY SELECTION:** From inception to July 10, 2020, repeated PubMed and open Web searches have been done by the scientific section collaborative group members of the European Society of Pediatric and Neonatal Intensive Care.

**DATA EXTRACTION:** There is little in the way of clinical research in children affected by coronavirus disease 2019, apart from descriptive data and epidemiology.

**DATA SYNTHESIS:** Even though basic treatment and organ support considerations seem not to differ much from other critical illness, such as pediatric septic shock and multiple organ failure, seen in PICUs, some specific issues must be considered when caring for children with severe coronavirus disease 2019 disease.

**CONCLUSIONS:** In this clinical guidance article, we review the current clinical knowledge of coronavirus disease 2019 disease in critically ill children and discuss some specific treatment concepts based mainly on expert opinion based on limited experience and the lack of any completed controlled trials in children at this time.

**KEY WORDS:** children; coronavirus; hypoxemic respiratory failure; multisystem inflammatory syndrome, pediatric intensive care

Coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) is usually mild in children, few require hospitalization and/or intensive care (1, 2), and death is rare (3). Like in adults, it is mainly, but not obligatorily, characterized by respiratory illness, fever, flu-like or abdominal symptoms, including diarrhea (1, 4).

Respiratory involvement varies from mild upper respiratory tract symptoms to severe acute respiratory distress syndrome (ARDS). Gattinoni et al (5)

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proposed two adult ARDS phenotypes of COVID-19 that may coexist: “Type L COVID-19 ARDS” characterized by intrapulmonary shunting, preserved compliance, less potential for lung recruitability, and increased alveolar dead space due to pulmonary microthrombi formation; “Type H”, a more “traditional” ARDS characterized by low compliance. These phenotypes have not been described in children, although some with multisystem inflammatory syndrome (MIS) (see below) show reduced lung compliance but near normal oxygenation (PC Rimensberger, unpublished observations, 2020 and reported by Chao [6]).

Recently, Pediatric MIS-Temporally associated with COVID-19 (PIMS-TS, later termed MIS-C in the United States and MIS by World Health Organization, which we use in this international article) has been reported (7–12). It is unknown if MIS is a postinfectious immune reaction with aberrant development of acquired immunity or a novel disease (11, 12).

A prodrome of lethargy and high temperature, with half reporting acute abdominal pain and diarrhea, is followed by a marked inflammatory multisystemic syndrome with either 1) a refractory “toxic” shock-like (TSS) syndrome with predominantly vasoplegic or cardiogenic shock or 2) a Kawasaki-like syndrome including coronary dilatation/aneurysms or a combination of both. MIS can occasionally be the “initial” presentation of COVID-19 (7, 9). Respiratory symptoms may not be present (11). Increased C-reactive protein, interleukin (IL) 1 and 6, mild to moderately elevated troponin, and high pro-BNP can be found (8–11).

This European Society of Pediatric and Neonatal Intensive Care (ESPNIC) statement provides recommendations for caring for children with suspected or proven SARS-CoV2 in intensive or intermediate care units. It builds on previous ESPNIC statements or consensus paper recommendations (13) unless otherwise stated, including pediatric guidance on septic shock (14), acute lung injury (15), noninvasive and invasive mechanical ventilation (16, 17), extracorporeal respiratory and/or circulatory support (extracorporeal membrane oxygenation [ECMO]) (18, 19), acute kidney injury (AKI) (20), nutrition (21, 22), Kawasaki disease (KD) (23), and emergency mass critical care (24).

## METHODOLOGY

The ESPNIC scientific group collaborative (two leading/writing members per section) worked with a

4-week timeline to draft recommendations. Given the paucity of pediatric COVID-19 outcome studies, the National Institutes of Health (NIH) consensus statement standards and Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach are not yet suitable (25).

Main PubMed search terms for repeated searches included coronavirus, COVID-19, SARS-CoV2, critical-illness, children, Kawasaki-like disease, MIS/PIMS-TS & MIS-C, and terms related to each section topic. Section leads selected section members based on their expertise for advice and validation of drafted recommendations. The authors (P.C.R., M.C.J.K., J.B.) coordinated the work and edited draft recommendations. Each modification was sent back to section leads for final approval.

## Basic Rules—Protect Yourself and Your Team

One or repeated nasal swab specimen negative polymerase chain reaction may occur and does not rule out COVID-19 (26). Thus, full personal protective equipment (PPE) should always be worn when caring for COVID-19 positive or suspected children. Aerosol-generating procedures (AGPs) (**Table 1**) are high-risk interventions and must be reduced to an absolute minimum.

## Respiratory Illness and Support

Pediatric Acute Lung Injury Consensus Conference and Pediatric Mechanical Ventilation Consensus Conference recommendations on respiratory support modes, strategies, and pulmonary ancillary treatment apply (15, 16). Of note, there is an increased risk of air-borne disease dissemination using noninvasive respiratory support (**Table 2**). Ideally, an adequate interface seal should be assured (e.g. helmet, nonvented oronasal or full-face mask) (27). Bacterial/viral filters (high-efficiency particulate air filter) must be placed at least on the expiratory limb of the patient circuit for invasive and noninvasive mechanical ventilation.

Delayed intubation is usually avoided in children with marked hypoxic-respiratory failure ( $\text{SpO}_2/\text{FiO}_2 < 221$ ) or with no improvement with NIV within 60–90 minutes (16, 17). However, higher intubation thresholds may be reasonable in proven COVID-19 hypoxic respiratory failure with low work of breathing and/or no pathologic hyperventilation.

**TABLE 1.**  
**Common Aerosol-Generating Events**

High-flow nasal cannula.
Continuous positive airway pressure or noninvasive ventilation without an adequate seal.
Bag-mask ventilation.
Intubation.
Any advertent or inadvertent circuit or endotracheal tube disconnection.
Tracheal suction (without a closed system).
Extubation.
Coughing/sneezing or any procedure inducing this.
Chest physiotherapy.
Delivery of nebulized medications (unless via closed circuit).
Cardiopulmonary resuscitation (prior to intubation).

Intubation should be performed by an expert in airway management in a closed environment with minimal staff present. Video laryngoscopy, rapid sequence induction, and avoiding bag/mask ventilation are recommended (28). If bag/mask ventilation cannot be avoided, the “two-person technique” is preferable to ensure better mask seal. Cuffed endotracheal tube should be used irrespective of patient age.

Measuring the quasi-static respiratory system compliance (Crs) under zero flow conditions after intubation, and then daily, allows identification of the clinical phenotype (i.e. with preserved or decreased Crs) and guides ventilator settings (Table 3).

### Microvascular Pulmonary Thrombosis, Pulmonary Embolism, and Thromboprophylaxis

Hypercoagulability, common in adults with COVID-19, has been observed in severely affected children, in whom we recommend a daily coagulation screen (D-dimer, prothrombin time, platelet count) (33) and pharmacologic thromboprophylaxis with either low weight molecular weight or unfractionated heparin (34)—based on renal function (creatinine clearance cut off value 30 mL/min).

**TABLE 2.**  
**General Recommendations for Patients Requiring Respiratory Support**

Strict personal protection equipment is mandated when managing patients, especially when handling airways, with suspected or confirmed coronavirus disease 2019.
Assure an adequate seal of the interphase for noninvasive ventilation.
Use cuffed ETTs for invasive ventilation.
Use bacterial/viral filters (high-efficiency particulate air filter) on the expiratory limb of the patient circuit.
Minimize ETT disconnections and use inline, closed suctioning.
Use airway humidification (active or passive), beware of endotracheal tube occlusion due to plugging caused by tenacious secretions.
Supportive care: fluid management, hemodynamic management, transfusion strategies, nutritional management, and sedation and analgesia practices should also be applied per Pediatric Acute Lung Injury Consensus Conference recommendations.

ETT = endotracheal tube.

In children with refractory hypoxia or right heart strain on electrocardiogram/echo, inferior vena cava signs, or raised D-dimers, we recommend screening for pulmonary embolism (PE) (e.g. ultrasound and/or CT-angiogram) and if found aggressive treatment: systemic anticoagulation is first line, but consider systemic thrombolysis or interventional radiology after multidisciplinary consultation for PE-induced hemodynamic compromise (34).

### Cardiovascular Involvement

There is no change to the 2020 Surviving Sepsis Campaign (SSC) “pediatric septic shock guidance” (14) recommended in children with COVID-19. Of note, hypovolemia is common following the vomiting and diarrheal prodrome with reduced fluid intake before ICU admission.

Specific MIS treatment (Fig. 1) should follow a multidisciplinary approach involving infectious diseases specialists, rheumatologists, cardiologists, and

**TABLE 3.**  
**Practice Recommendation for Coronavirus Disease 2019 Children on Invasive Mechanical Ventilation**

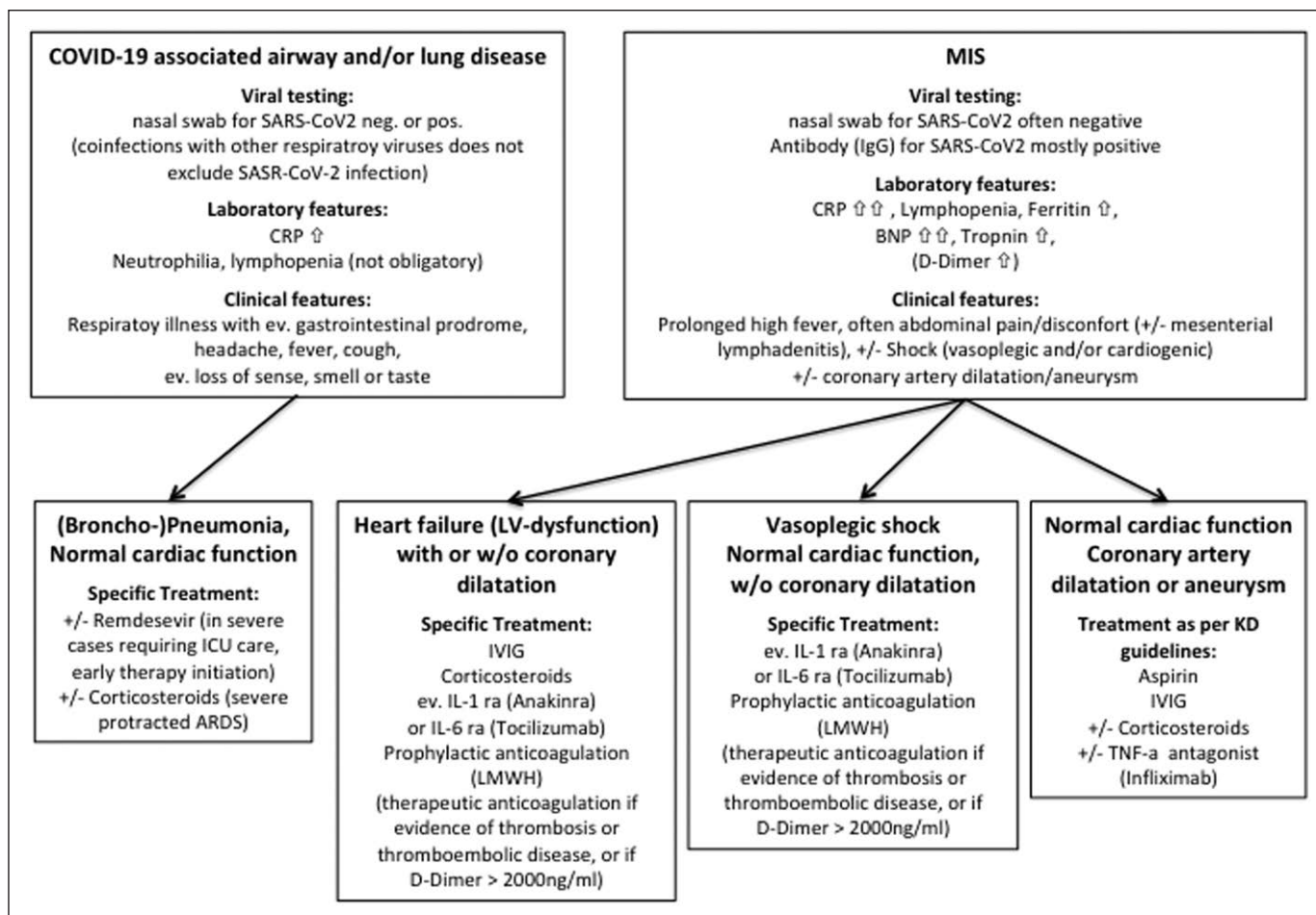
Ventilator settings	Initial settings
Vt–expiratory	5–7 mL/kg ideal bodyweight, lower Vt may be targeted if decreased lung compliance.
PEEP and FiO <sub>2</sub>	Initial PEEP ± 8–10 cm H <sub>2</sub> O <sup>a</sup> —further increase based on guidance from the low PEEP/FiO <sub>2</sub> grid (29) <sup>b</sup> .  Titration of PEEP/FiO <sub>2</sub> to maintain oxygen saturation 92–96% for moderate or 88–92% for severe pediatric acute respiratory distress syndrome
Goals and limits	Values
Driving pressure	≤ 15 cm H <sub>2</sub> O
Pplat	< 28–32 cm H <sub>2</sub> O
pH	> 7.20
Supportive measures	Specific recommendation
Neuromuscular blockade	Consider early use of neuromuscular blocking agents for 24–48 hr if Pao <sub>2</sub> /FiO <sub>2</sub> < 150; OI ≥ 16; OSI ≥ 10, and/or if there is spontaneous breathing at high (esophageal) transpulmonary pressures, minimizing ventilator dyssynchrony, prone positioning, and avoiding high Pplat.
Prone positioning	Consider early use of neuromuscular blocking agents for 24–48 hr if Pao <sub>2</sub> /FiO <sub>2</sub> < 150; OI ≥ 16; OSI ≥ 10, especially if there is concomitant reduced lung compliance.
Escalating therapies for refractory hypoxemia	Proposed clinical approach
PEEP/recruitment	Titrate PEEP, balancing oxygenation, and hemodynamics. High PEEP may be necessary if low lung compliance.
iNO	Use iNO if documented pulmonary hypertension and/or right ventricular dysfunction/failure.  Consider iNO if alteration in hypoxic pulmonary vasoconstriction is presumed (i.e. lack of improvement in oxygenation despite all other measures).  With acute onset of marked hypoxemia consider pulmonary embolism (D-dimers, ultrasound, CT thorax).
HFOV	HFOV may be considered in patients with poor lung compliance (i.e. requiring inspiratory airway pressures during conventional mechanical ventilation of 30 cm H <sub>2</sub> O or higher to maintain acceptable ventilation ([i.e. pH > 7.20]) and/or oxygenation despite adequate PEEP settings.  We recommend staircase titration of mean airway pressure according to the oxygenation response (30, 31).
Respiratory ECMO	May be considered if refractory hypoxemia persists despite all measures used.

HFOV = high-frequency oscillatory ventilation, iNO = inhaled nitric oxide, OI = oxygenation index, OSI = oxygen saturation index, PEEP = positive end-expiratory pressure, Pplat = plateau pressure, Vt = tidal volume.

<sup>a</sup>Lower initial PEEP levels should be considered in patients with preserved compliance (“Type L” lung disease [5]) indicating “non”-recrutable lung disease.

<sup>b</sup> PEEP levels below the PEEP/FiO<sub>2</sub> grid have shown to be associated with increased mortality in pediatric acute respiratory distress syndrome (32).





**Figure 1.** Proposed specific treatment options (beyond basic ICU treatment concepts) for coronavirus disease 2019 (COVID-19)–related severe respiratory disease (SARS) and multisystem inflammatory syndrome (MIS). ARDS = acute respiratory distress syndrome, BNP = brain natriuretic peptide, CRP = C reactive protein, CoV2 = coronavirus 2, KD = Kawasaki disease, IgG = immunoglobulin G, IL = interleukin, IVIG = IV immunoglobulin, LMWH = low molecular weight heparin, LV = left ventricular, TNF-α = tumor necrosis factor-α.

intensivists. In Kawasaki-like or TSS presentations (e.g. hyperinflammatory shock) especially when myocardial dysfunction is documented, successful use of IV immunoglobulin administered early as per KD guidelines (23) has been reported (9–11) and can be recommended, acknowledging this is not based on data for the TSS-like presentation. Besides IVIG, steroids are the most frequently used anti-inflammatory drug (8–11). In the event of resistance to IVIG and persistent high inflammatory markers, anti-IL-6 monoclonal antibody (Tocilizumab, Sarilumab), IL-1 receptor antagonist (Anakinra), or tumor necrosis factor-α antagonist (Infliximab) has been used on an empirical basis (9, 11). However, according to NIH COVID-19 treatment guidelines (July 17, 2020), there are insufficient data yet to recommend for or against the use of either IL-6 or IL-1 inhibitors (35).

In cardiovascular compromise/hemodynamic instability, repeated multimodal hemodynamic monitoring, including point of care ultrasound (36), can optimize therapy. With documented myocardial and/or coronary involvement, serial and follow-up echocardiography by a pediatric cardiologist is important and might allow for an eventual better understanding of this novel disease for which the Initial early prognosis seems good (9).

COVID-19 is not a contraindication to ECMO in children, the present indications and thresholds for ECMO as per currently published extracorporeal life support organization (ELSO) guidelines apply (18). Shock refractory to standard management should prompt early consultation with ECMO providers (19) although specific COVID-19 ECMO data in the context of MIS are sparse (9, 11). In line with interim ELSO

COVID-19 guidelines (18), we do not recommend extracorporeal cardiopulmonary resuscitation outside an ICU setting and without an experienced team.

## AKI and Renal Replacement Therapies

Although the epidemiology and etiology of COVID-19 AKI may differ slightly from other types of critical illness, management is essentially the same (20). Unless there is a situation such as severe sepsis where continuous renal replacement therapy (CRRT) is clearly superior to peritoneal dialysis (PD) allowing hemodynamic stability and more accurate fluid removal (37), both methods are equally efficacious (38).

Given the COVID-19 cytokine storm, other extracorporeal therapies (e.g. hemoperfusion and cytoadsorption) have been proposed in COVID-19 ICU patients with AKI to remove proinflammatory cytokines (39), thereby reducing cytokine storm induced organ damage. With minimal supportive data and the risk of therapeutic drug removal, as well as poor availability, we do not currently recommend them.

**Adaptation of Renal Replacement Therapy Regimens With Resource Limitation.** With resource limitations, renal replacement therapy (RRT) regimens can be adapted. 1) Single machine use for two or more patients by increasing exchange rates to compensate for decreased RRT time (31). 2) Use of lower rates after achieving metabolic control to limit consumable waste (32). 3) If CRRT unavailable, PD may be used (38).

**Risks of Filter Clotting During CRRT.** The hypercoagulable COVID-19 state means frequent filter clotting, and vascular thrombosis can be an issue, so the usual approach of prefilter heparin is recommended (20) (Table 4). Many adults with COVID-19 have had deranged liver function tests (LFTs) (40), so citrate has been relatively contraindicated. Cautious use in children is permitted, although few have had deranged LFTs to date. Alternatively, a combination of prostacyclin and unfractionated heparin (both pre filter) can be used.

## Neurologic Involvement

COVID-19, as with other viral infections, can cause rare but important neurologic manifestations in children (e.g., meningitis, encephalitis, acute disseminated encephalomyelitis, postinfectious brainstem encephalitis, Guillain-Barre syndrome, myositis, acute

**TABLE 4.**  
**Measures to Reduce the Risk of Filter Clotting During Continuous Renal Replacement Therapy**

Address all issues related to vascular catheter—size, location, bending, kinking, leakage.

Higher blood flow rates and predilution replacement fluid administration reduces the chances of clotting of the filter.

Preferring filters with larger surface area to reduce transmembrane pressure.

While using continuous veno-venous hemodiafiltration, reduce the postfilter component to avoid clotting in the bubble trap.

Dose heparin infusion appropriately. Follow practical tips from the Kidney Disease Improving Global Organization guidelines [18].

Consider using a heparin bolus 20 U/kg.

Start prefilter heparin at higher than usual rates 20–30 U/kg/hr (usual 10–20 U/kg/hr).

Maintain ACT 180–220 s, if ACT is low and the filter clots— increase the dose by 10–20% of the previous dose.

Heparin 10 U/kg/hr and prostacyclin 4 ng/kg/min can be combined as anticoagulants.

While using citrate regional anticoagulation, aim for lower ionized calcium levels in the circuit: 0.2 mmol/L instead of the usual 0.3–0.4 mmol/L.

Heparin and citrate can be combined as well. Unfractionated heparin is infused directly into the patient at a dose of 10 U/kg/hr whilst citrate is administered regionally at the usual dose  $-1.5 \times$  blood flow rate (citrate dose might have to be increased) with calcium infusion (calcium chloride or calcium gluconate).

ACT = activated clotting time.

necrotizing hemorrhagic encephalopathy, and anoxia [41–43]).

COVID-19 can present atypically in both adults and children with nonspecific neurologic symptoms (e.g. headache, dizziness, impairment of taste and smell, seizures, neck stiffness, photophobia, altered mental state, behavioral changes, and movement disorders [9, 11, 43]). Thus, clinicians should consider COVID-19

in children presenting with new-onset neurologic symptoms. Infant COVID-19–associated seizures have been reported (44), and current status epilepticus management guidelines should be followed and neurophysiologic monitoring considered in high-risk patients (45, 46). Hypercoagulable state in COVID-19 predispose patients to a risk of acute cerebrovascular disease (23) and early neuroimaging with CT or MRI in patients with neurologic symptoms will assist diagnosis.

### Anti-Inflammatory, Antiviral Treatment, and Antibacterial Treatment

Evidence for best practice and recommendations around antiviral and anti-inflammatory treatment in COVID-19 is rapidly evolving, and—given the relative rarity of severe COVID-19 presentations in children—infectious diseases and immunology experts should be consulted early and treatments determined by consensus with families. For compassionate use, bioethics support is also warranted, and the risk of innovative therapy must be fully explained to the family. However, if formal clinical trials are available, children should be enrolled (47).

**Antibacterial Treatment.** Critically ill children with respiratory or systemic disease are much more likely to suffer from bacterial or other viral infections, which should be promptly treated as per the SSC guidelines even during the COVID-19 pandemic (14). The principals of antimicrobial stewardship should be followed.

**Anti-Inflammatory Treatment.** Consider systemic anti-inflammatory treatment (e.g. high-dose steroids) in unstable patients with MIS. Immunomodulation (e.g. targeted IL-6 antagonists such as Tocilizumab or IL-1 receptor antagonist [Anakinra]) in patients with hyperexpression of several cytokines including IL-6 and IL-1 $\beta$ , hyperferritinemia, and thrombocytopenia (i.e. cytokine storm) should remain limited to clinical trials (47).

**Antiviral Therapies.** In severe COVID-19–related respiratory illness, empirical antiviral agents can be considered, whereas as MIS is likely to be a postinfectious syndrome they should not (11, 12).

Based on adult data, remdesivir is the preferred antiviral drug for compassionate use in children (48). The U.S. Food and Drug Administration has authorized it as an investigational antiviral drug (emergency use authorization May 1, 2020) (49). Lopinavir/ritonavir, a

protease inhibitor, may be considered if remdesivir is unavailable (50).

### Nutritional Support

Usual ICU nutritional practice (21, 22) is recommended. Specific COVID-19 aspects are as follows: Enteral feeding tube placement and aspiration are potential AGP so 1) decrease exposure by quicker gastric tube placement rather than postpyloric tubes and 2) avoid measuring gastric residual volumes, which has limited evidence.

### Neonatal and Pediatric Transport: Specific Considerations

Additional recommendations to existing transport policies for the transport of both suspected and SARS-CoV2 proven children, either inside or between hospitals, are necessary, primarily to protect the team involved.

SARS-CoV2 status of an infant or child must be determined at referral, so staff, PPE, and equipment can be prepared as well as referring and receiving unit secure pathways for the transfer team within the hospital to avoid cross-contamination of clean areas/staff. We recommend that the team transporting children with suspected/confirmed COVID-19 must wear full PPE. For staff (i.e. ambulance drivers, paramedics) not directly involved inpatient care but coming into their close proximity (< 2 m) (e.g. loading/unloading stretcher), at least reduced PPE is mandatory. Patients, if self-ventilating, should wear a surgical mask whenever feasible to minimize aerosol spread. The risk of AGP during transport conditions, with staff wearing full PPE, is greater than in ICU; hence, a lower threshold for pretransport intubation to avoid emergency intubation during transport is justified.

For pediatric stretcher transports closed transport capsules, if available and the child's condition allows, reduce aerosol spread. Air conditioning/ventilation must, if possible, be set to extract to avoid air recirculation. Counterintuitively as it is contrary to family centered care, infants and children should be transported without their parents or relatives present.

At the destination, designated areas must be available for PPE doffing by transport staff. After the transport exposed transport equipment including equipment left in the transport vehicle (i.e. not within closed compartments) requires decontamination with a universal detergent, followed by cleaning of the entire interior



of the vehicle with a chlorine-based solution at 1,000 parts per million (51).

## Nursing Care

Protection of nursing personnel is paramount, with full PPE available and used effectively to minimize contamination. The primary goals of nursing care must be rethought during a pandemic (e.g. organization and function of a unit and its staff [24]), with some nursing protocols adapted or modified.

The number of caregivers and time in a bed-space can be minimized, for example, use of extenders (deployed personnel) who remain outside patient's immediate area/dedicated "infectious" zone to prepare drugs, organize/set-up devices, and communicate between ward control/nurse in charge and the bedside nurse.

The use of consumables such as in-line suction catheters and ventilator circuits must be considered both are able to be used for up to 7 days (52, 53). Fundamental nursing care should be clustered (12 hr) to reduce nursing exposure and promote physiologic stability. This includes eye care, oral care, washing, and pressure area prevention to reduce iatrogenic injury (54). Safe and prolonged prone positioning is also helpful in pediatric COVID-19 pneumonitis and safer using a checklist (55).

The nursing workload model must change from usual patient-centered model to task delivery allocation ensuring vital care (e.g. proning, medication) is completed safely and effectively despite fewer qualified staff. Reduced nurse:patient ratios place significant stress on the whole team, changing standards from "ideal" to best possible critical care with the resources available.

Finally, a vital nursing role during COVID-19 is to promote and optimize family/parent involvement in care despite significantly restricted visitation. Consistent daily family communication is essential, that is, video-conferencing (56, 57). Reducing the child and family's fear of staff in full PPE is essential, requiring careful developmentally appropriate explanations and the use of play (56).

## Visiting and Spiritual Care

Restrictions on visiting are at odds with usual PICU family-centered care. Families in self-isolation or with COVID-19 are usually not permitted into hospitals to protect other children, parents/families, and staff from

infection. In exceptional circumstances, such as imminent or actual bereavement, full PPE can be worn by the individuals affected. Otherwise restricted visiting, such as one parent and no siblings, has become usual. Novel ways to enable contact such as video-conferencing with boyfriend/girlfriend and school friends should be instituted for teenagers. The psychologic distress for the parents of critically ill children, compounded by the removal of primary support mechanisms, is being witnessed by many of us and worthy of formal study. The dehumanizing effects of PPE, the absence of relatives, and even personal effects are concerning too. Compassionate exceptions to restricted visiting policies should be considered in specific situations, but the risk to healthcare teams is also worrying (58).

Spiritual support should be offered on request given that as religion and spirituality provide the foundation for many people's morality. Consultation with faith or nonfaith (philosophical, psychologic or pastoral) support must be offered and can include religious rites performed by video link. Faith/spiritual/other supportive care must also be available for staff, particularly those struggling with the dehumanizing aspect and the tough decisions being made and their results.

## Ethical Considerations

The COVID-19 triaging decisions required by "adult" colleagues have not been necessary in children with their lower disease severity. It is worth noting the complex pediatric population may become an issue in another pandemic or even a second wave (59).

Rather than direct infection, the COVID-19 ethical issues affecting children and PICU teams are the loss of other healthcare opportunities with major cancelled surgery, clinics and other issues, social isolation, and education issues, and for staff, PPE availability, reduced parent presence with sick children, and moral injury to those deployed to adult services who have seen/made rapid existential decisions.

Difficult treatment decisions during a pandemic must comply with relevant ethical principles, and independent ethics support must be available for both clinicians and families (60).

## CONCLUSIONS

COVID-19 in children has been thought to be mild and mainly, yet not obligatory, characterized by



respiratory illness, fever, flu-like symptoms, and only rarely progressing to severe hypoxic-respiratory failure. However, recently the MIS was described in children, although whether this represents an acute inflammatory manifestation of COVID-19, a postinfectious immune reaction or different disease remains unclear. Suitable registries are urgently required for this purpose.

The majority of our recommendations for children with COVID-19 are essentially the same as for any critically ill child, for example, noninvasive or invasive mechanical ventilation, cardiac failure, pediatric sepsis, and multiple organ failure. We have highlighted those areas where there is enough clinical experience or specific concern to amend current recommendations.

Many involve the risk to staff, for example, PPE and transport and reduced staff and family numbers in PICU. Anti-inflammatory and infective approaches, for example, immunomodulation and antiviral therapies, are suggested but are largely considered on a compassionate basis as controlled studies do not exist.

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Members of the European Society of Pediatric and Neonatal Intensive Care (ESPNIC) Scientific Sections' Collaborative Group are listed in the **Appendix**.

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## REFERENCES

- Ong JSM, Tosoni A, Kim Y, et al: Coronavirus disease 2019 in critically ill children: A narrative review of the literature. *Pediatr Crit Care Med* 2020; 21:662–666
- Castagnoli R, Votto M, Licari A, et al: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in children and adolescents: A systematic review. *JAMA Pediatr* 2020; 174:882–889
- Dong Y, Mo X, Hu Y, et al: Epidemiology of COVID-19 among children in China. *Pediatrics* 2020; 145:e20200702
- Response Team CDC COVID-19: Coronavirus disease 2019 in children – United States, February 12–April 2, 2020. *MMWR Morb Mortal Wkly Rep* 2020; 69:422–426
- Gattinoni L, Chiumello D, Caironi P, et al: COVID-19 pneumonia: Different respiratory treatments for different phenotypes? *Intensive Care Med* 2020; 46:1099–1102
- Chao JY, Derespina KR, Herold BC, et al: Clinical characteristics and outcomes of hospitalized and critically ill children and adolescents with coronavirus disease 2019 at a tertiary care medical center in New York City. *J Pediatr* 2020; 223:14–19.e2
- Royal College of Paediatrics and Child Health: Guidance: Paediatric Multisystem Inflammatory Syndrome Temporally Associated With COVID-19. 2020. Available at: <https://www.rcpch.ac.uk/sites/default/files/2020-05/COVID-19-Paediatric-multisystem-inflammatory-syndrome-20200501.pdf>. Accessed May 2, 2020
- Riphagen S, Gomez X, Gonzalez-Martinez C, et al: Hyper inflammatory shock in children during COVID-19 pandemic. *Lancet* 2020; 395:1607–1608
- Belhadj Z, Meot M, Bajolle F, et al: Acute heart failure in multisystem inflammatory syndrome in children (MIS-C) in the context of global SARS-CoV-2 pandemic. *Circulation* 2020
- Verdoni L, Mazza A, Gervasoni A, et al: An outbreak of severe Kawasaki-like disease at the Italian epicentre of the SARS-CoV-2 epidemic: An observational cohort study. *Lancet* 2020; 395:1771–1778
- Whittaker E, Bamford A, Kenny J, et al: Clinical characteristics of 58 children with a pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2. *JAMA* 2020; 324:259–269
- Belot A, Antona D, Renolleau S, et al: SARS-CoV-2-related paediatric inflammatory multisystem syndrome, an epidemiological study, France, 1 March to 17 May 2020. *Euro Surveill* 2020; 25:2001010
- European Society of Paediatric and Neonatal Intensive Care (ESPNIC): Standards and Guidelines. Available at: <https://espnice-online.org/Education/Standards-and-Guidelines>. Accessed April 22, 2020
- Weiss SL, Peters MJ, Alhazzani W, et al: Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children. *Intensive Care Med* 2020; 46:10–67
- Pediatric Acute Lung Injury Consensus Conference Group: Pediatric acute respiratory distress syndrome: Consensus recommendations from the Pediatric Acute Lung Injury Consensus Conference. *Pediatr Crit Care Med* 2015; 16:428–439
- Kneyber MCJ, de Luca D, Calderini E, et al: Section Respiratory Failure of the European Society for Paediatric and Neonatal Intensive Care: Recommendations for mechanical ventilation of critically ill children from the paediatric mechanical ventilation consensus conference (PEMVECC). *Intensive Care Med* 2017; 43:1764–1780
- Rimensberger PC, Cheifetz IM; Pediatric Acute Lung Injury Consensus Conference Group: Ventilatory support in children with pediatric acute respiratory distress syndrome: Proceedings from the pediatric acute lung injury consensus conference. *Pediatr Crit Care Med* 2015; 16:S51–S60
- Shekar K, Badulak J, Peek G, et al: Extracorporeal Life Support Organization Coronavirus Disease 2019 Interim Guidelines: A consensus document from an international group of interdisciplinary extracorporeal membrane oxygenation providers. *ASAIO J* 2020; 66:707–721
- MacLaren G, Fisher D, Brodie D: Preparing for the most critically ill patients with COVID-19: The potential role of extracorporeal membrane oxygenation. *JAMA* 2020; 323:1245–1246
- Khwaja A: KDIGO clinical practice guidelines for acute kidney injury. *Nephron Clin Pract* 2012; 120:c179–c184
- Mehta NM, Skillman HE, Irving SY, et al: Guidelines for the provision and assessment of nutrition support therapy in the pediatric critically ill patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition. *Pediatr Crit Care Med* 2017; 18:675–715
- Tume LN, Valla FV, Joosten K, et al: Nutritional support for children during critical illness: European Society of Pediatric and Neonatal Intensive Care (ESPNIC) metabolism, endocrine and nutrition section position statement and clinical recommendations. *Intensive Care Med* 2020; 46:411–425
- McCrindle BW, Rowley AH, Newburger JW, et al: American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee of the Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Cardiovascular Surgery and Anesthesia;

- and Council on Epidemiology and Prevention: Diagnosis, treatment, and long-term management of Kawasaki disease: A scientific statement for health professionals from the American Heart Association. *Circulation* 2017; 135:e927–e999
24. Kissoon N; Task Force for Pediatric Emergency Mass Critical Care: Deliberations and recommendations of the pediatric emergency mass critical care task force: executive summary. *Pediatr Crit Care Med* 2011; 12:S103–S108
  25. Guyatt GH, Oxman AD, Vist GE, et al; GRADE Working Group: GRADE: An emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008; 336:924–926
  26. Sethuraman N, Jeremiah SS, Ryo A: Interpreting diagnostic tests for SARS-CoV-2. *JAMA* 2020; 323:2249–2251
  27. Hui DS, Chow BK, Lo T, et al: Exhaled air dispersion during high-flow nasal cannula therapy versus CPAP via different masks. *Eur Respir J* 2019; 53:1802339
  28. Matava CT, Kovatsis PG, Lee JK, et al; PeDI-Collaborative: Pediatric airway management in COVID-19 patients: Consensus guidelines from the Society for Pediatric Anesthesia's Pediatric Difficult Intubation Collaborative and the Canadian Pediatric Anesthesia Society. *Anesth Analg* 2020; 131:61–73
  29. Acute Respiratory Distress Syndrome Network, Brower RG, Matthay MA, et al: Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med* 2000; 342:1301–1308
  30. Khemani RG, Parvathaneni K, Yehya N, et al: Positive end-expiratory pressure lower than the ARDS Network protocol is associated with higher pediatric acute respiratory distress syndrome mortality. *Am J Respir Crit Care Med* 2018; 198:77–89
  31. Bellomo R, Cass A, Cole L, et al; RENAL Replacement Therapy Study Investigators: Intensity of continuous renal-replacement therapy in critically ill patients. *N Engl J Med* 2009; 361:1627–1638
  32. Moriguchi T, Harii N, Goto J, et al: A first case of meningitis/encephalitis associated with SARS-Coronavirus-2. *Int J Infect Dis* 2020; 94:55–58
  33. Levi M, Thachil J, Iba T, et al: Coagulation abnormalities and thrombosis in patients with COVID-19. *Lancet Haematol* 2020; 7:e438–e440
  34. Loi M, Branchford B, Kim J, et al: COVID-19 anticoagulation recommendations in children. *Pediatr Blood Cancer* 2020; e28485
  35. NIH COVID-19 Treatment Guidelines: Immune-Based Therapy Under Evaluation for Treatment of COVID-19. Available at: <https://www.covid19treatmentguidelines.nih.gov/immune-based-therapy/>. Accessed July 28, 2020
  36. Singh Y, Tissot C, Fraga MV, et al: International evidence-based guidelines on Point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC). *Crit Care* 2020; 24:65
  37. Vanholder R, Van Biesen W, Hoste E, et al: Pro/con debate: Continuous versus intermittent dialysis for acute kidney injury: A never-ending story yet approaching the finish? *Crit Care* 2011; 15:204
  38. Chionh CY, Soni SS, Finkelstein FO, et al: Use of peritoneal dialysis in AKI: A systematic review. *Clin J Am Soc Nephrol* 2013; 8:1649–1660
  39. Ronco C, Reis T, Husain-Syed F: Management of acute kidney injury in patients with COVID-19. *Lancet Respir Med* 2020; 8:738–742
  40. Cai Q, Huang D, Yu H, et al: COVID-19: Abnormal liver function tests. *J Hepatol* 2020; 73:566–574
  41. Mao L, Jin H, Wang M, et al: Neurologic manifestations of hospitalized patients with Coronavirus disease 2019 in Wuhan, China. *JAMA Neurol* 2020; 77:683–690
  42. Paterson RW, Brown RL, Benjamin L, et al: The emerging spectrum of COVID-19 neurology: Clinical, radiological and laboratory findings. *Brain* 2020; awaa240
  43. Asadi-Pooya AA, Simani L: Central nervous system manifestations of COVID-19: A systematic review. *J Neurol Sci* 2020; 413:116832
  44. Dugue R, Cay-Martínez KC, Thakur KT, et al: Neurologic manifestations in an infant with COVID-19. *Neurology* 2020; 94:1100–1102
  45. Rowberry T, Kanthimathinathan HK, George F, et al: Implementation and early evaluation of a quantitative electroencephalography program for seizure detection in the PICU. *Pediatr Crit Care Med* 2020; 21:543–549
  46. Wijdicks EF, Rabinstein AA, Bamlet WR, et al: FOUR score and glasgow coma scale in predicting outcome of comatose patients: A pooled analysis. *Neurology* 2011; 77:84–85
  47. Bhimraj A, Morgan RL, Hirsch Shumaker A, et al: Infectious Diseases Society of America Guidelines on the Treatment and Management of Patients with COVID-19. 2020. Available at: <https://www.idsociety.org/practice-guideline/covid-19-guideline-treatment-and-management/>. Accessed April 22, 2020
  48. Chiotos K, Hayes M, Kimberlin DW, et al: Multicenter initial guidance on use of antivirals for children with COVID-19/SARS-CoV-2. *J Pediatric Infect Dis Soc* 2020; piaa045
  49. U.S. Food & Drug Administration (FDA): Coronavirus (COVID-19) Update: FDA Issues Emergency Use Authorization for Potential COVID-19 Treatment. FDA News release. 2020. Available at: <https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-issues-emergency-use-authorization-potential-covid-19-treatment>. Accessed May 20, 2020
  50. Cao B, Wang Y, Wen D, et al: A trial of lopinavir-ritonavir in adults hospitalized with severe Covid-19. *N Engl J Med* 2020; 382:1787–1799
  51. Kampf G, Todt D, Pfaender S, et al: Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J Hosp Infect* 2020; 104:246–251
  52. Kollef MH, Prentice D, Shapiro SD, et al: Mechanical ventilation with or without daily changes of in-line suction catheters. *Am J Respir Crit Care Med* 1997; 156:466–472

53. Samransamruajkit R, Jirapaiboonsuk S, Siritantiwat S, et al: Effect of frequency of ventilator circuit changes (3 vs 7 days) on the rate of ventilator-associated pneumonia in PICU. *J Crit Care* 2010; 25:56–61
54. Berry AM, Davidson PM, Nicholson L, et al: Consensus based clinical guideline for oral hygiene in the critically ill. *Intensive Crit Care Nurs* 2011; 27:180–185
55. Oliveira VM, Piekala DM, Deponti GN, et al: Safe prone checklist: Construction and implementation of a tool for performing the prone maneuver. *Rev Bras Ter Intensiva* 2017; 29:131–141
56. Davies HD, Byington CL; Committee On Infectious Diseases: Parental presence during treatment of Ebola or other highly consequential infection. *Pediatrics* 2016; 138:e20161891
57. Mason KE, Urbansky H, Crocker L, et al; Task Force for Pediatric Emergency Mass Critical Care: Pediatric emergency mass critical care: Focus on family-centered care. *Pediatr Crit Care Med* 2011; 12:S157–S162
58. Virani AK, Puls HT, Mitsos R, et al: Benefits and risks of visitor restrictions for hospitalized children during the COVID pandemic. *Pediatrics* 2020; 146:e2020000786
59. Brierley J, Playfor S, Ray S: Planning for the next pandemic: A call for new guidance. *Lancet Respir Med* 2020; 8:228–229
60. Haward MF, Moore GP, Lantos J, et al: Paediatric ethical issues during the COVID-19 pandemic are not just about ventilator triage. *Acta Paediatr* 2020; 109:1519–1521

## APPENDIX

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